Updated DOE Solid-State Lighting Research & Development Agenda

The 2nd Annual DOE Solid-State Lighting Program Planning Workshop provides a forum for updating and prioritizing the DOE SSL R&D agenda. To facilitate that process, DOE requested that participants complete an assignment prior to the Workshop. The Department prepared an updated version of its Solid-State Lighting R&D agenda based on comments from many stakeholders and researchers from industry, academia, and the National labs.

The attached pages present the updated Solid-State Lighting Research & Development Agenda. It is divided into four groups:

Group 1. Inorganic SSL "Core Technology" Research
Group 2. Inorganic SSL "Product Development"
Group 3. Organic SSL "Core Technology" Research
Group 4. Organic SSL "Product Development"

Within each of the four grouped topic areas, the Department's SSL R&D agenda is broken down by tasks and subtasks. During Day 2 of the Workshop, participants will discuss and prioritize each of the tasks and subtasks, which will impact future DOE SSL solicitations.

Group 1. Inorganic SSL "Core Technology" Research

The bullets are descriptive examples and do not represent an exhaustive list or priority areas of research.

1.1. Inorganic Materials Research
Goal: increase internal quantum efficiency

1.1.1. Large-area substrates, buffer layers, and wafer research
- Low defect density
- Existing and alternate low-cost substrates

1.1.2. High-efficiency semiconductor materials
- Efficient broadband materials (including orange, yellow-green, and UV (360nm to 410nm))
- Existing and alternate low-cost materials (e.g. nitride materials)
- p-doping and charge mobility studies

1.1.3. Reliability and defect physics for improved LED lifetime
- Dopant and defect physics, device characterization and modeling
- Droop (reduced efficiency at high temperature and current density)

1.2. Inorganic Device Architecture Research and Modeling
Goal: increase external quantum efficiency

1.2.1. Device approaches, structures and systems
- Lasers, resonant cavities
- Nanocomposite sources (e.g., photonic crystals & microcavity effects)
- Surface plasmons

1.2.2. Strategies for improved light extraction and manipulation
- Optical and device modeling for general illumination

1.3. Inorganic Technology Integration
Goal: research technology for high performance LED lamps and luminaires

1.3.1. Phosphors and conversion materials
- Deposition methods and technology, layer packing
- Long-life, heat tolerant (e.g., nanophosphors)

1.3.2. Encapsulants and packaging materials
- High temperature, long-life, UV-tolerant, improved optical extraction (e.g., nanocomposites)
- Thermal management strategies and modeling

1.3.3. Electrodes and interconnects

- Ultra-low resistance
- Piezoelectric contacts

1.3.4. Measurement metrics and human factors
- Productivity, preference, and demonstrations
- Use-dependent metrics for white light
- Standards for electrical and photometric measurement
- Binning strategies

1.4. Inorganic Growth and Fabrication Processes and Manufacturing Issues
Goal: cross-cutting improvements to growth and fabrication processes and manufacturing

1.4.1. Physical, chemical, and optical modeling for epitaxial processes

1.4.2. Design and development of in-situ diagnostic tools for the epitaxial process

1.4.3. Research into low-cost, high-efficiency reactor designs and manufacturing methods

1.4.4. Investigation (theoretical and experimental) of die separation, chip shaping, and wafer bonding techniques

Total for Group 1. Inorganic SSL "Core Technology" Research: 4 tasks and 13 subtasks.

Group 2. Inorganic SSL "Product Development"

The bullets are descriptive examples and do not represent an exhaustive list or priority areas of research.

2.1. Inorganic Materials Development

Goal: develop devices with increased internal quantum efficiency

2.1.1. Substrate, buffer layer and wafer engineering and development

2.1.2. High-efficiency semiconductor materials

- Efficient broadband light emitting materials (including yellow-green, orange, and UV (360nm to 410nm))
- Existing and alternate low-cost materials (e.g., nitride materials)

2.2. Inorganic Device Architecture Development

Goal: develop devices with increased external quantum efficiency

2.2.1. Implementing strategies for improved light extraction and manipulation

- High refractive index encapsulants for improved light extraction
- Large-area light extraction and current injection

2.2.2. Device architectures with high power-conversion efficiencies

- Chip scaling and micro-arrays
- Multi-color chips, arrays on a single substrate

2.3. Inorganic Technology Integration

Goal: develop cost-effective LED lamps and luminaires

2.3.1. Manufactured materials

- Phosphors and luminescent materials
- High temperature encapsulants and mounting materials

2.3.2. LED packages and packaging materials

- Ultra-low resistance contacts, tunnel contacts
- Heat dissipation techniques

2.3.3. Modeling, distribution and coupling issues (chip, device and component level)

- Secondary optics design
- Computer modeling and analysis tools

2.3.4. Luminaire design, engineered applications, field tests and demonstrations

- Practical retrofit lamp designs (e.g., low-voltage reflector (MR-16), screw-in replacements (A-19), integrated solutions (distributed lighting))
- New installation luminaire designs
- Advanced electronics (e.g., standardization, color control)

2.4. Inorganic Growth and Fabrication Processes and Manufacturing Issues
Goal: develop equipment and tools for low-cost, high-yield manufacturing and scaling to larger wafers

2.4.1. Incorporate proven in-situ diagnostic tools into existing equipment

2.4.2. Develop low-cost, high-efficiency reactor designs

2.4.3. Develop techniques for die separation, chip shaping, and wafer bonding

Total for Group 2. Inorganic SSL "Product Development": 4 tasks and 11 subtasks.

Group 3. Organic SSL "Core Technology" Research

The bullets are descriptive examples and do not represent an exhaustive list or priority areas of research.

3.1. Organic Materials Research

Goal: increase internal quantum efficiency through enabling physics and chemistry

3.1.1. Electro-active organic materials substrate research

3.1.2. High-efficiency, low-voltage, stable materials (host, dopant and transport layers)
- Stable hole and electron blocking layers
- Single and multilayered devices

3.1.3. Improved contact materials and surface modification techniques to improve charge injection
- n and p doped polymers
- Molecular dopants

3.2. Organic Device Architecture Research and Modeling

Goal: increase external quantum efficiency

3.2.1. Strategies for improved light extraction and manipulation
- Optical and device modeling for general illumination

3.2.2. Approaches, structures and systems for improved-performance low-cost white-light devices

3.2.3. Transparent electrode research

3.3. Organic Technology Integration

Goal: research technology for high performance OLED lamps and luminaires

3.3.1. Phosphors and conversion materials

3.3.2. Encapsulation and packaging materials

3.3.3. Electrodes and interconnects

3.3.4. Measurement metrics and human factors
- Productivity, preference, and demonstrations
- Standards for electrical and photometric measurement

3.4. Organic Growth and Fabrication Processes and Manufacturing Issues

Goal: develop equipment and tools for low-cost, high-yield manufacturing

3.4.1. Physical, chemical and optical modeling for fabrication of OLED devices

3.4.2. Tools and methods for manufacturing
- In-situ diagnostic tools
- Organic material purity

3.4.3. Investigation (theoretical and experimental) of low-cost fabrication and patterning techniques

Total for Group 3. Organic SSL "Core Technology" Research: 4 tasks and 13 subtasks.

Group 4. Organic SSL "Product Development"

The bullets are descriptive examples and do not represent an exhaustive list or priority areas of research.

4.1. Organic Materials Development

Goal: develop devices with increased internal quantum efficiency

4.1.1. Electro-active organic materials substrate development

4.1.2. High-efficiency, low-voltage stable materials (host, dopant and transport layers)

4.1.3. Improved contact materials and surface modification techniques to improve charge injection

4.2. Organic Device Architecture Development

Goal: develop devices with increased external quantum efficiency

4.2.1. Implementing strategies for improved light extraction and manipulation

4.2.2. Develop architectures that improve device robustness, increase lifetime and increase efficiency

4.2.3. Demonstrate device architectures: e.g., white-light engines (multi-color versus single emission)

4.3. Organic Technology Integration

Goal: develop efficient and reliable OLED lamps and luminaires

4.3.1. OLED packaging for lighting applications

- Heat management and dissipation techniques
- Encapsulants to create robust devices
- Down-conversion materials for maximizing high-quality lumen output

4.3.2. Characterization tools for modeling OLED devices

4.3.3. Voltage conversion, current density and power distribution

4.3.4. Luminaire design, engineered applications, field tests and demonstrations

4.4. Organic Growth and Fabrication Processes and Manufacturing Issues

Goal: develop equipment and tools for low-cost, high-yield manufacturing

4.4.1. Module and process optimization and manufacturing

- Large-area coating and deposition
- Flexible substrates for roll-to-roll manufacturing

4.4.2. Synthesis of active OLED materials

Total for Group 4. Organic SSL "Product Development": 4 tasks and 12 subtasks.